CQ Researcher

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Fish Farming

Is it safe for humans and the environment?

Global demand for fish products has doubled since the 1950s and is still rising. Today more than 40 percent of the world's seafood comes not from wild catches but from land-based and offshore farms. With many wild fisheries already overharvested throughout the world, aquaculture is an important food source — especially for poor countries — and has made seafood more abundant and affordable. But some fish farms pollute surrounding waters, and escaped farm fish compete with wild stocks and spread diseases. Moreover, raising carnivorous fish can use up more fish protein for feed than it produces, further stressing wild fisheries. There are also growing concerns about whether imported seafood is safe to eat and whether the United States regulates fish imports strictly enough. Congress is considering legislation to expand ocean aquaculture, but many fish and marine experts urge caution, saying we know little about the potential impact on the oceans.



The new face of farming: Butch Medlin of New Haven, Ill., is all smiles after switching from raising hogs to striped bass. "Both are an awful lot of work," he says.

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Fish Farming

By Jennifer Weeks

The Issues

At the Portland Fish Exchange, a long warehouse beside Maine's Casco Bay, seafood processors and wholesalers wave their numbers as the auctioneer takes bids on haddock, flounder and other fish fresh off the boat. The exchange handled 30 million pounds of fish per year in the early 1990s, but this year it may sell as little as 5 million pounds. Reasons for the decline include limits on the number of days fishermen can spend at sea and a state ban on selling lobsters accidentally caught in trolling nets. [1]

Fifty miles south and six miles off the coast, the new face of the seafood industry can be seen. Using underwater cages, the University of New Hampshire's Atlantic Marine Aquaculture Center has raised 3,000 pounds of halibut and 15,000 pounds of haddock here since 2004. The project is also demonstrating a method for growing mussels on lines suspended 40 feet below the surface.



Getty Images/*The Christian Science Monitor*/John Nordell

Fishermen harvest scallops grown in cages in Massachusetts' Nasketucket Bay. Aquaculture provided an estimated 44 percent of the seafood used for global human consumption in 2005, and experts predict fish farms may soon outproduce wild fisheries. Fish raised on land in tanks or ponds make up 85 percent of both global and U.S. production, but many environmentalists worry the growing use of coastal and offshore operations could foul the seas or allow farmed fish to escape and breed with wild species.

"Twenty-five years ago, I was a commercial fisherman in the Gulf of Maine," Richard Langan, director of the university's Open Ocean Aquaculture Project, told a Senate subcommittee in 2006. "One night when I was at the wheel, I looked out the pilothouse window and saw the lights from what must have been at least 50 boats, all doing the same thing as ours — catching as many fish as fast as they could. . . . It was clear to me that New England's commercial fisheries could not sustain that level of exploitation and that there had to be a better way to provide seafood and make a living." [2]

Experts disagree over whether fish farming is providing that better way. But there's no question it is supplying more seafood than ever. In 2005 aquaculture provided an estimated 44 percent of the seafood used for global human consumption, and experts predict that by 2012 fish farms may outproduce wild fisheries. [3] In the early 1950s fish farms produced less than 1 million tons of seafood per year. By 2004 they were raising 60 million tons of finfish, shellfish and aquatic plants annually worth about $70 billion.

But many environmental and health advocates worry that marine fish farms — especially for large species like salmon, tuna and cod — could foul the oceans. Critics call ocean fish farms "floating feedlots" and say that they have the same potential to become serious pollution sources as large livestock farms. [4]

"We cannot afford to make the same mistakes with ocean agriculture that we have made on land," a task force on marine aquaculture convened by the Woods Hole Oceanographic Institution (WHOI) in Massachusetts warned in a 2007 report. The study concluded that ocean fish farming done properly offered significant health, economic and environmental benefits. Implemented carelessly, however, it could pollute ocean waters, disrupt wild fisheries, introduce exotic species that might become pests and compete with already-stressed wild stocks. [5]

"If you cram enough animals into enclosures at high density, you're going to see pollution. And if you crowd animals together, they're going to be stressed and share their parasites and diseases," says task force member Rebecca Goldburg, a senior scientist with the advocacy group Environmental Defense. "There's plenty of room for aquaculture to learn from the problems of the animal production industry, but we're still figuring out the right system for offshore operations."

Two forces are driving the explosion in aquaculture, known as the Blue Revolution. Many of the world's major wild, or "capture," fisheries have been overharvested and are producing flat or declining yields. Meanwhile, demand for seafood is climbing. Fish is a cheap source of protein in developing countries, and medical experts are telling consumers in industrialized nations to eat more heart-healthy seafood products and less red meat.

Consumption of Farmed Seafood Is Rising

Aquaculture accounted for nearly half of all seafood eaten worldwide in 2005, compared with slightly more than a third in 2000. During the same period, total consumption of seafood (both farmed and wild) rose to nearly 100 million tons.

Human Consumption of Farm-Raised Seafood
(in millions of tons)

Year	Total seafood consumption	Aquaculture consumption
2000	87.3	32.0
2001	89.8	34.2
2002	90.0	36.4
2003	92.5	38.5
2004	95.0	40.9
2005	96.5	43.0

Source: "The State of World Fisheries and Aquaculture 2006," Food and Agriculture Organization of the United Nations, 2007

Many Americans apparently are following doctors' orders. U.S. per-capita seafood consumption increased by 30 percent from 1980 through 2005, in part because aquaculture made seafood more available and affordable. [6] Most farmed seafood comes from China and other countries whose output dwarfs U.S. production. (*See chart, p. 629.*) The United States imports 80 percent of its seafood for human consumption, including some 2 million tons of farmed products each year. If domestic aquaculture production does not rise, the "seafood trade gap" could grow to 4 million tons per year by 2025, according to the National Oceanographic and Atmospheric Administration (NOAA). [7]

"Globally, aquaculture is growing pretty well, but in the U.S. it's slowing down," says Randy MacMillan, president of the National Aquaculture Association. "Our producers are very efficient and have excellent-quality products, but cheaper imports are flooding the market, and they can't compete. The catfish industry, which is one of our biggest drivers, is taking ponds out of production because of imports from China and Vietnam and economic fraud from mislabeled foreign fish."

In a rare prosecution last year, a seafood trader in Panama City, Fla., was sentenced to four years in prison and fined $1.1 million for selling 1.6 million pounds of Vietnamese basa catfish falsely labeled as more expensive species like bass and grouper. [8]

To meet rising demand for seafood and reduce pressure on wild fisheries, NOAA wants to expand the U.S. aquaculture industry from $1 billion to $5 billion in annual revenues by 2025. The agency has proposed legislation that would allow aquaculture operations in waters under federal control, between three and 200 miles offshore. Marine fish farms currently operate in state waters, which extend three miles offshore along most U.S. coastlines.

"The United States accounts for only 1 percent of the global $70 billion per year aquaculture industry," said Commerce Secretary Carlos Gutierrez in March, announcing the offshore legislation. "The U.S. is not in the game, and this bill will help the U.S. compete in this highly profitable industry."

Aquaculture is a diverse business with products ranging from seaweed and tropical aquarium fish to 1,000-pound bluefin tuna. Freshwater fish raised on land in tanks or ponds make up about 85 percent of both global and U.S. production, but saltwater fish are winning a growing share of the market. Two of the most popular types of seafood in the United States, salmon and shrimp, come predominantly from fish farms.

Due to fish migration patterns, breeding seasons, weather and other constraints, good-quality supplies of many wild fish are only available for a few months each year. For example, folk wisdom once held that oysters should only be eaten during months with an "R" (September through April) because warm waters encourage the growth of bacteria in shellfish and because oysters are less flavorful during summer spawning. But worldwide farming has made many types of oysters and other seafood available year-round.

"Farmed products give our menu more stability," says Roger Berkowitz, president of the 35-resturant Legal Sea Foods chain, which also sells many types of wild-caught fish. "You don't always know when wild species will be available."

From a health perspective, more fish is a good thing. Both the U.S. Department of Agriculture and the American Heart Association recommend fish as a source of lean protein and omega-3 fatty acids, which reduce the incidence of cardiovascular disease. [9] Oily fish such as salmon, anchovies and herring are especially good sources of key fatty acids.

Some analysts, however, have raised concerns about pollutants in farmed fish, especially imports. Consumer advocates, U.S. fish farmers, and state

officials criticize the Food and Drug Administration (FDA) for inadequately policing imported fish. "We're letting tainted products come into the United States with improper testing," says Barry Costa-Pierce, a professor of fisheries and aquaculture at the University of Rhode Island. "Everybody in the scientific community knows about these issues, but there's no government hammer behind them."

Whether and how to expand U.S. fish farming is part of a broader discussion about the state of the oceans and fisheries. Since 2003 two high-level expert commissions — the government-appointed U.S. Commission on Ocean Policy and the privately funded Pew Oceans Commission — have warned that pollution, overfishing and coastal development pose serious threats to the world's oceans. [10] Congress, states and the Bush administration have taken some steps in response, such as overhauling national policies for managing wild fisheries.

But big-picture ocean aquaculture issues remain unsettled, experts say. "Many new uses are being proposed for the oceans, including offshore wind farms and energy ports," says University of New Hampshire Professor Andrew Rosenberg, a member of the U.S. Commission on Ocean Policy and former deputy director of the National Marine Fisheries Service. "All of these uses require exclusive use of ocean space and raise environmental concerns. We really don't have any consistent management system to decide who gets to use what piece of the ocean bottom on an exclusive basis."

As lawmakers, scientists and conservationists debate the pros and cons of aquaculture, here are some of the questions they are asking:

China Leads in Aquaculture Production

China raised more than 27 million tons of seafood from 2002-2004 — nearly two-thirds of the 45 million tons of total global aquaculture production. The United States ranked 10th.

Top 10 Aquaculture Producers in 2004

Rank (2004)	Country	No. of tons (2002-2004)	Annual growth
1.	China	27,553,471	5.0%
2.	India	2,225,102	6.3
3.	Vietnam	1,078,755	30.6
4.	Thailand	1,055,579	10.8
5.	Indonesia	940,546	6.9
6.	Bangladesh	823,277	7.8
7.	Japan	698,779	-3.1
8.	Chile	607,481	11.2
9.	Norway	574,194	7.7
10.	United States	545,894	10.4
	Rest of the World	**4,818,443**	**7.3**
	World Total	**45.5 million**	**6.1**

Source: "The State of World Fisheries and Aquaculture 2006," Food and Agriculture Organization of the United Nations, 2007

Are farmed fish safe to eat?

In the wild, salmon eat tiny shrimp called krill and a variety of other fish. Farmed salmon eat processed feeds that contain fish meal and fish oil from smaller fish like anchovies and herring. Indiana University chemist Ronald Hites and his colleagues identified these feeds as likely culprits in a 2004 study that found higher levels of PCBs, dioxins and other organichlorine pesticides in farmed salmon than in wild salmon. They concluded that salmon farming produced fish containing potentially dangerous concentrations of pollutants because toxins from smaller fish that foraged in polluted waters were concentrated in the feed stocks. [11]

FDA officials replied that the levels of contaminants in farmed salmon did not pose health risks and that farmed salmon was safe to eat. [12] Some producers argued that the study obscured different life histories and feeding habits among wild salmon species, which caused different contaminant levels. They also noted that consumers received much larger doses from meat and dairy products. "No matter how the data [are] calculated and no matter whose PCB values for salmon are used, the amount of PCBs contributed to the diet from farmed or most wild salmon is truly insignificant in the context of overall PCB intake of the average American," Ronald Hardy, director of the University of Idaho's Aquaculture Research Institute, wrote in 2005. [13]

The controversy spurred more research. Several studies indicated that substituting vegetable oil for fish oil in feeds reduced PCB and dioxin levels in farmed fish. [14] A Canadian study found that while farmed salmon generally had higher PCB levels than wild species, all concentrations were at least 50-fold lower than U.S. and Canadian levels of concern, and levels in

different types of wild salmon varied widely. [15]

Medical experts stress the bigger health picture. A 2006 article in the *Journal of the American Medical Association* reviewed findings from more than 200 studies and concluded that for most adults, health benefits from eating one or two servings of fish weekly outweighed risks from contaminants. The authors estimated coronary heart disease benefits outweighed cancer risks by up to 370-fold for farmed salmon and by 300-fold to more than 1,000-fold for wild salmon. [16]

"The benefits of fish are well established, while the risks are overblown," said Harvard Medical School Assistant Professor Dariush Mozaffarian, a co-author of the article. [17]

But other problem substances are turning up in imported farmed seafood, much of which comes from countries that allow producers to use drugs and chemicals banned in the United States. One of the most controversial products is farmed shrimp, which has become a large-scale industry in South and Central America and Asia.

Cramming shrimp into ponds makes them vulnerable to diseases and parasites, so shrimp farms in developing countries often use antibiotics, disinfectants and pesticides to keep animals healthy. But certain antibiotics can cause illnesses. For example, some nitrofurans are carcinogenic, and chloramphenicol causes two types of anemia in humans. [18] Others, such as ciprofloxacin, are used in both animal and human medicine, and their overuse threatens human health by creating drug-resistant bacteria that can be passed on to humans in tainted seafood. [19] Fungicides also pose health threats: Malachite green is suspected in genetic mutations, and gentian violet has been linked to mouth cancer.

These additives are banned in the United States, but many have turned up in imported shrimp. According to the advocacy group Food & Water Watch, the FDA rejected 2,817 seafood shipments containing antibiotic residues in 2005 even though it only tested 1.2 percent of all imported seafood. [20] U.S. inspections have detected proscribed antibiotics and fungicides in shrimp from Vietnam, Venezuela, Thailand, Malaysia and Mexico, as well as in Asian catfish, tilapia and eel. [21]



AP Photo/Ric Francis

Hybrid striped bass are netted at the Kent Seatech facility near Palm Springs, Calif. The United States accounts for only 1 percent of the global $70 billion aquaculture industry. To help expand U.S. output, the National Oceanic and Atmospheric Administration has proposed allowing aquaculture operations in offshore federal waters.

U.S. producers argue their competitors gain an economic edge by raising fish in dirty water and crowded conditions, then dosing them with chemicals to keep them healthy. "The United States has a very stringent regulatory system to review drugs for aquaculture," says the National Aquaculture Association's MacMillan. "That process does not exist in China, Vietnam or some other countries that export seafood here."

Not all imported seafood is tainted. Legal Sea Foods restaurants buy farmed shrimp from sources including Thailand, Vietnam and the Philippines. "I've found over the years that farmed shrimp is a far more consistent product than wild, because people in the U.S. just don't know how to handle shrimp," says company president Berkowitz. "Domestic boats add a lot of chemicals to the product and don't ice it properly, but with farmed shrimp we can dictate the quality that we want."

Legal Sea Foods tests fish at its own in-house laboratory, but most consumers rely on inspections by the FDA. [22] Reports in 2001 and 2004 by the U.S. General Accounting Office (now the Government Accountability Office [GAO]) warned the FDA was not doing enough to improve the safety of imported seafood, mainly because the agency was not putting priority on establishing "equivalence agreements" with seafood-exporting countries. These voluntary agreements document that exporting nations have seafood-safety systems equivalent to U.S. regulations. The GAO also found that the FDA was not quickly reporting problems with imported seafood to port inspectors. [23]

Critics want more oversight of the rising tide of foreign seafood. "About 1 percent of imported seafood is sent to a lab and tested. That's pretty startling considering that seafood causes 18 to 20 percent of food-borne illnesses," says Wenonah Hauter, executive director of Food & Water Watch. "FDA doesn't

have the resources or staff to really inspect seafood imports. We hear lots of rhetoric about homeland security, but what about homeland food security?"

FDA officials acknowledge they need more support to police imported food, drugs and other goods. "The world has globalized, and all this stuff is coming in from outside the United States, but the regulations and procedures we have in place really did not contemplate this change," chief medical officer Janet Woodcock said last month. [24]

Taking matters into their own hands, Alabama, Louisiana, and Mississippi — major producers of farm-raised catfish — this year banned Chinese and Vietnamese catfish containing prohibited antibiotics. On June 28 the FDA issued an import alert blocking all imports of Chinese farmed catfish, basa, shrimp, dace (a type of carp) and eel unless they tested negative for nitrofurans, fluoroquinolones, malachite green and gentian violet. [25]

"We're taking this strong step because of current and continuing evidence that certain Chinese aquaculture products . . . contain illegal substances that are not permitted in seafood sold in the United States," said David Acheson, FDA assistant commissioner for food protection. [26] According to the FDA, contaminant levels in Chinese fish were very low and posed a risk mainly from long-term exposure.

Not all problems stem from imports. In late May melamine, an industrial chemical not authorized in food products, was found in shrimp feed made in Ohio. Earlier this spring, thousands of pets across the United States were killed or sickened by pet foods containing melamine that was traced back to China. The Ohio producer, Tembec, tested its feed ingredients after hearing about the pet food problems. "They just asked themselves, 'I wonder what's in this stuff? I wonder if we have anything in here that shouldn't be in here?' " said a company spokesman. [27]

Carp Is Top Aquaculture Species

Carp and other members of the cyprinid family, such as barbs and chubs, are by far the most widely cultivated type of fish. Many shellfish and mollusks are also among the top 10 aquaculture species.

Top Ten Aquaculture Species, 2004

Rank	Species	Production (in tons)	Annual Growth (2002-2004)
1	Carps and other cyprinids	16,473,462	4.8%
2	Oysters	4,143,345	3.1
3	Clams, cockles, arkshells	3,705,155	9.1
4	Miscellaneous freshwater fish	3,365,954	-0.3
5	Shrimps, prawns	2,228,421	28.7
6	Salmons, trouts, smelts	1,780,298	5.1
7	Mussels	1,674,224	4.6
8	Tilapias and other cichlids	1,640,471	10.9
9	Scallops, pectens	1,050,080	-2.6
10	Miscellaneous marine mollusks	958,672	-12.4

Source: "The State of World Fisheries and Aquaculture 2006," Food and Agriculture Organization of the United Nations, 2007

Is aquaculture polluting the oceans?

Oceans cover almost three-quarters of Earth's surface to an average depth of 2.5 miles. Until recently, few people imagined that human actions could have lasting effects on such vast expanses of water. But recent studies show that overfishing, coastal development, offshore oil drilling and other activities are polluting the seas and damaging marine habitats. [28] Harmful aquaculture practices can make the situation worse.

Marine aquaculture operations raise fish in cages and so-called netpens that allow currents to carry their wastes into the surrounding environment. Discharges of dissolved nutrients, uneaten feed, fish sewage and dead fish cause a form of pollution called eutrophication. Algae and plankton feed on these materials and multiply, then are broken down by bacteria when they die. The decomposition process consumes dissolved oxygen from surrounding water and sediments, making the area less able to support life.

Eutrophication degrades nearby coral reefs and seagrass beds and reduces biodiversity. Some studies have found that surrounding areas recovered quickly when farming stopped, but in other cases impacts persisted several years later. [29] On a local scale, fish farms can be serious pollution sources: An average-size salmon farm with 200,000 fish produces as much fecal matter as a city of 65,000 people. [30]

In its January 2007 report the Woods Hole Marine Aquaculture Task Force concluded that discharges from U.S. fish farms were small compared to other water pollution sources, but it warned that little was known about how well the oceans could absorb these pollutants. Impacts could be much more serious if aquaculture increases, the group warned, especially if fish farms are sited close together.

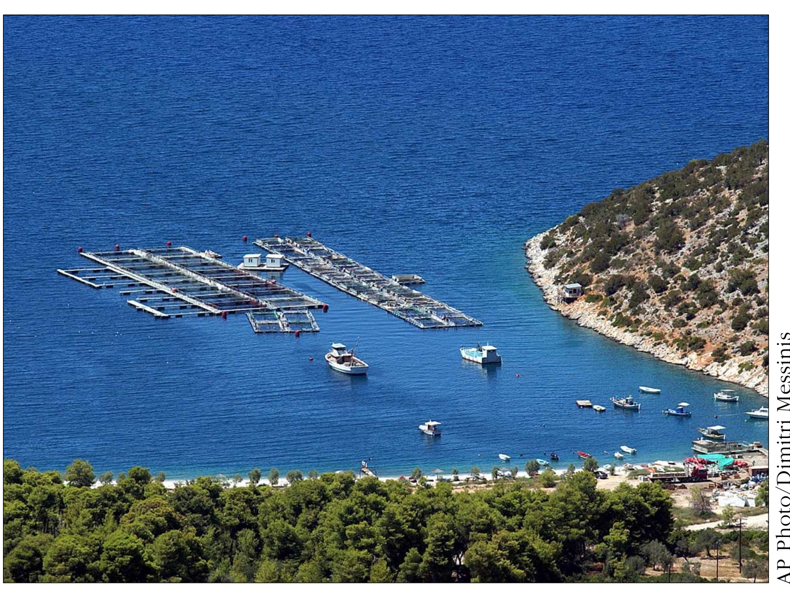
Furthermore, the United States does not have legal guidelines for ocean water quality as it does for drinking water. "Without federal standards for marine water quality, there's really no way to measure whether marine waters are being polluted by aquaculture," says Goldburg of Environmental Defense. The Clean Water Act requires marine aquaculture farms to apply for discharge permits and employ so-called "best management practices" to limit pollution, but states have broad discretion to define those practices. "EPA and the states need to develop marine water-quality standards so they can measure whether waters are being impaired by all kinds of offshore development, not just fish farms," Goldburg contends.

Many aquaculture operators say they already are strictly regulated and that marine fish farms will not harm the oceans. "Environmental stewardship is crucial to aquaculture," says MacMillan of the National Aquaculture Association. "Our industry in the United States has only developed in the past 20 years, so we've grown up in a very different environmental and regulatory climate than land-based agriculture. Expectations for us are far more demanding."

The University of New Hampshire's Rosenberg disagrees. "Our environmental standards for aquaculture aren't more stringent than regulations in other countries, they're vaguer," he says. "That's one reason why U.S. production hasn't grown faster — we don't have a clear set of guidelines for how it should be done. We need a policy that recognizes environmental concerns like pollution discharges and the spread of diseases to wild stocks."

Aquaculture can also cause "biological pollution" — interbreeding between wild fish and escaped farm fish. Such genetic mixing produces hybrid offspring that are less well-adapted to survive. A decade-long study in Ireland found that hybrid offspring of wild and farmed salmon had lower survival rates at sea than wild salmon and that 70 percent of second-generation hybrids died within a few weeks of hatching. [31] Similarly, in Norway — where about half a million farmed salmon and sea trout escape each year — hybrid salmon survive and return to rivers for spawning at lower rates than wild fish. [32]

Marine experts worry biological pollution will become more serious as fish farms move offshore, where hurricanes are strong enough to damage oil drilling rigs weighing thousands of tons. "Systems out in the open ocean will be hit by storms, so we have to make sure the biological impacts of escaped fish are as small as possible," says Goldburg. "Unless they can show that escapes pose a very low risk, growers should only produce native fish species from local genotypes that won't cause harm if they mix with wild fish."



AP Photo/Dimitri Messinis

Greece's coastline offers ideal conditions for fish farming, one of the country's fastest-growing industries. Greece produces about 60 percent of the European Union's sea bass and sea bream, the most popular species in the Mediterranean region.

Others say the issue is manageable. "Whenever fish escapes happen, it makes headlines," says George Nardi, co-founder and chief technology officer at GreatBay Aquaculture in New Hampshire, which is working to commercialize offshore Atlantic cod farming in submersible cages. "The failure gets attention, but no one talks about how many fish are put into tanks and cages every day without any problems. We should put escapes in perspective, learn how to minimize problems and work on the animals that go in so that they don't harm the environment if they do escape."

Some kinds of aquaculture make water cleaner. Bivalve shellfish (species with two hinged shells like oysters, clams and mussels) filter seawater and feed on plankton and suspended particles in the water. By doing so, they control plankton levels and improve water clarity, which helps sunlight penetrate the water and promotes marine plant growth. Mature oysters can filter up to 55 gallons of water per day. [33]

Making more space for shellfish aquaculture can help reduce nutrient overloads that cause algae blooms and eutrophication. "Shellfish are by far the most cost-effective strategy to control pollution," says Woods Hole Oceanographic Institute researcher Hauke Kite-Powell, who is studying shellfish farming for water cleanup at Waquoit Bay in southeastern Massachusetts. [34]

Seafood Safety Information Often Confusing

Study calls for better advice on risks, benefits

Seafood is good for you — unless it's contaminated with mercury, which can cause profound neurological damage — or PCBs, which may cause cancer, say government and private health experts.

But while some farmed fish may have more contaminants than wild fish, chemical levels in both types of fish typically are below government advisory levels, according to government scientists.

With mixed messages like these coming from government agencies and private health groups, it's not surprising there's confusion about how much and what kinds of fish to eat. Health and consumer advocates worry that unclear and conflicting advisories could drive people away from eating the right kinds of seafood. Conversely, some warnings may not keep consumers away from risky species or adequately protect at-risk groups like pregnant women.

For example, in 2004 the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) issued a joint advisory warning pregnant women, those who might become pregnant, nursing mothers and young children to avoid shark, swordfish, tilefish and king mackerel — large wild-caught predatory fish that contained high mercury levels. The advisory also recommended limiting consumption of albacore tuna, which contains more mercury than other varieties. [1]

But a survey two years later by the Center for Science in the Public Interest found that only 20 percent of respondents could identify the high-risk fish, and that a comparable number incorrectly thought salmon was high in mercury. The group argued that consumers could not be relied on to remember which fish species were safe to eat and called for mandatory warning notices at seafood counters and on fish packages. [2]

Producers object to mandatory labeling, but California requires retailers to post warnings at seafood counters, and some large grocery chains do so voluntarily at stores nationwide.

Other problems include conflicting state and local warnings — which can recommend different consumption levels of the same species of fish from the same watershed — and getting safety information to ethnic and minority groups that are heavy fish consumers. Some communities have found that personal contact with anglers is a more effective way to raise awareness of risks than simply publishing brochures or posting them on the Internet. Even when warned, however, many people who fish in local waters continue to eat fish. [3]

In any event, Americans are eating less seafood than the levels recommended by the American Heart Association and other health groups, according to a 2006 report from the Institute of Medicine (IOM) of the National Academy of Sciences. [4] Additionally, some of the most widely consumed types, such as salmon and shrimp, contain low amounts of the omega-3 fatty acids that confer important health benefits. The study also found that consumer advice on seafood choices from government agencies and private groups was uncoordinated and fragmented, used inconsistent portion sizes and treated benefits separately from risks.

"We need better work on risk communication," says Malden Nesheim, emeritus professor of nutrition at Cornell University and chair of the study. "Seafood is a good food, and people ought to be consuming it, but there are certain segments of the population that need to be careful, mainly children and pregnant women."

It's not clear whether the relative risks and benefits of eating seafood are understood, Nesheim adds. "We don't have a lot of good data to go by. There's anecdotal evidence that some people stopped eating all fish after the FDA-EPA advisory on mercury was issued, but we can't confirm that."

The IOM study concluded government agencies need to know more about seafood-consumption patterns and levels of nutrients and contaminants in common types of seafood. To help consumers, the IOM urged federal agencies to develop new tools, such as interactive Web-based programs, that users could program with specific information about their ages and risk factors.

"There are health messages that everyone of a certain generation has heard — 'Just Say No' — but like shoes, advice is more helpful if it is sized appropriately and designed appropriately for the intended use," the report observed. [5]

[1] "What You Need to Know About Mercury in Fish and Shellfish," Department of Health and Human Services and Environmental Protection Agency, March 2004, www.cfsan.fda.gov/~dms/admehg3.html.

[2] Center for Science in the Public Interest, "Is It High or Is It Low?" July 6, 2006.

[3] Karl Blankenship, "Despite Advisories, Study Finds Many Still Eating Tainted Fish," *Bay Journal*, May 2005; Bill Novak, "Catch of the Day: Good Info," *Capital Times* (Madison, Wis.), Sept. 15, 2006, p. B1.

[4] Institute of Medicine, *Seafood Choices: Balancing Benefits and Risks* (2006).

[5] *Ibid.*, p. 241.

A traditional aquaculture approach called polyculture — growing fish near shellfish and seaweed that feed on fish wastes — is receiving increasing attention from large-scale producers. This makes environmental sense, says Goldburg: "Recycling nutrients is a foundation of sustainable agriculture. You get another crop, and you cut pollution."

Polyculture is widely used in Asia, but most major Western producers have not adopted the practice yet. Applied on a large scale, it could produce enough fish, shellfish and seaweed to meet growing world demand for seafood over the next several decades, scientists predict. [35] But consumers would have to eat more marine plants and shellfish and fewer of the popular, large carnivorous fish and shrimp that generate aquaculture's worst environmental impacts.

Should the United States commercialize genetically engineered fish?

For $5, hobbyists curious about seafood trends can buy a genetically altered fish at pet stores throughout the United States. The GloFish, the only so-called transgenic fish approved for commercial sale, is produced by injecting a fluorescent protein gene derived from jellyfish and sea anemones into the eggs of zebrafish, a common tropical aquarium species. Mature GloFish, which glow bright green, orange or red, pass fluorescence genes on to their offspring.

Conventional zebrafish are widely used in medical research because they grow quickly, their immune systems are similar to those of humans and their embryos are transparent, so scientists can see early developmental stages clearly. Fluorescent zebrafish technology offers researchers some new options — for example, tinting certain genes or organs to make it easier to watch them develop. [36]

Biotechnology companies are also working on food species. Massachusetts-based Aqua Bounty Technologies is seeking FDA approval for AquAdvantage salmon, which have been genetically modified to grow year-round, not just in summer. The company says AquAdvantage fish will reach market size twice as fast as conventional salmon, saving farmers money on feed and releasing fewer waste products into the oceans. [37]

Researchers worldwide are studying ways to genetically modify many seafood and aquatic plants to make them grow faster, convert feed to body mass more efficiently, resist disease, tolerate cold water or produce useful substances for food, pharmaceuticals and cosmetics. These genetically modified organisms (GMOs) could lower seafood production costs and reduce the need for antibiotics in fish farming. Scientists are also working on products that change color when they detect contaminants in water (the original goal for GloFish) or shellfish engineered to grow without producing proteins that trigger allergic reactions in some consumers. [38]

Many experts worry about health and environmental impacts from transgenic fish. A 2002 National Academy of Sciences study identified several moderately risky substances that might be found in genetically modified (GM) animals, including new proteins that trigger allergies, biologically active substances such as growth hormones and toxic metabolites created through the genetic engineering process. [39]

The report also warned of environmental impacts if GMOs escaped into the wild. "Animals that become feral easily, are highly mobile and have a history of causing extensive community damage" pose the biggest environmental threats, the study concluded. [40] Fish and shellfish fall into this category.

If engineered strains escape from farms in areas where they have no natural predators, they could spread and become invasive. Transgenic fish could also compete with or prey on wild species, especially if they have been altered to grow quickly and eat at higher rates. "GMOs have different properties from conventional species," says the University of New Hampshire's Rosenberg. "They might be conduits for diseases or parasites, so what happens if they escape? Producers may say the odds are 95 percent against escape, but other things work 95 percent of the time too, like condoms, and that's not always good enough."

One way to reduce escape risks is to alter the chromosomes of GMOs so they cannot reproduce in the wild. By subjecting newly fertilized eggs to extreme temperatures, high pressure, or certain chemicals, scientists can produce "triploid" individuals with three sets of chromosomes, which are infertile. Triploidy has been used to reduce escape threats from conventional finfish. But it can be hard to verify that large batches of eggs have been completely sterilized, and a few unaffected eggs in large batches could easily go unnoticed. [41] Another option is to raise finfish stocks that are all male or all female so that escaped fish cannot reproduce in the wild.

Some scientists question whether genetic manipulation adds much value over traditional breeding techniques that humans have used for centuries to modify plants and animals. Aquaculture is already bringing fish and marine plants under cultivation about 100 times faster than land plants and animals were domesticated, and humans are farming a larger share of known aquatic species than of known land species, even though land agriculture developed some 11,000 years ago. [42]

"We don't need to do gene jockeying with fish," says the University of Rhode Island's Costa-Pierce. "With conventional animal breeding technologies we can get phenomenal gains in growth and other favorable characteristics. I doubt there's a big market for GM fish in North America, so why go down a path of conflict and controversy that could undercut markets for conventional products?"

Many Americans unknowingly eat or use products made from GM crops. [43] In 2006, crops engineered to tolerate herbicides or resist pests accounted for 89 percent of the soybeans planted in the United States, 40 percent of corn and 57 percent of cotton. [44] But surveys show Americans are more comfortable with GM plants than with animals. [45]

"Big corporate producers are very worried about the consumer response to transgenic fish," says Stanford University economist Rosamond Naylor. "Most producers don't want GM fish introduced because they'll run into market constraints in Europe and other places where buyers don't want it." California, Oregon, and Washington state have banned raising GM fish in state waters, and Maryland passed a

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Chronology

2500 B.C.-Early 1700s

Small-scale aquaculture develops in ancient China, Egypt, Japan.

1800-1900

Aquaculture develops in U.S.

1853
Ohio trout farm artificially fertilizes brook trout eggs.

1871
Congress creates U.S. Fish Commission, which develops a system of federal hatcheries.

1870s-1900s
U.S. rivers, lakes and coastal waters stocked with trout and other species.

1900-1960s

Aquaculture becomes professionalized, with support from universities and government.

1909
First commercial U.S. trout farm established in Idaho.

1910-1930
State and federal researchers develop methods for farming channel catfish.

1938
Mitchell Act funds hatcheries in the Pacific Northwest to replace wild salmon and steelhead spawning grounds blocked or flooded by hydroelectric dams.

1930s-1940s
Franklin D. Roosevelt administration supports construction of fish ponds on farms to aid soil and water conservation and generate income.

1940s-1960s
Farming of tilapia, shrimp and channel catfish develops in United States.

1970s-1980s

Rising world population helps drive global aquaculture boom. Concerns emerge about water pollution, wild fisheries and contamination in farmed fish.

1970s
U.S. catfish farm acreage hits 40,000 in 1970, up from 400 acres in 1960. Salmon, abalone and mussel farming develop in the United States.

1972
Congress passes Clean Water, Coastal Zone Management and Marine Mammal Protection acts.

1980
National Aquaculture Act promotes U.S. aquaculture, but federal agencies fail to develop a comprehensive system for regulating fish farming. . . . Sturgeon farming begins in California. . . . Massachusetts starts farming quahogs (hard clams).

1989
Alaska bans farming of large ocean fish, such as salmon, in state waters, to protect wild fisheries from escaped farm fish.

1990s-2000s

Restrictions are imposed on aquaculture in response to harmful impacts. U.S. considers fish farms in federal waters.

1995
U.N. Food and Agriculture Organization adopts code of conduct for responsible fisheries.

1997
Washington state classifies escaped Atlantic salmon from fish farms as a "living pollutant."

2000
An estimated 100,000 salmon escape from Maine fish farm.

2003
Pew Oceans Commission recommends moratorium on new marine finfish farms until Congress legislates standards for sustainable aquaculture. . . . Federal judge rules salmon farms in Maine are violating Clean Water Act.

2004
U.S. Commission on Ocean Policy endorses Pew report, calls for "a coordinated and consistent policy" for aquaculture development. . . . *Science* reports farmed salmon contain higher levels of contaminants than wild salmon.

2005
National Oceanographic and Atmospheric Administration (NOAA) proposes legislation to create regulatory framework for aquaculture in federal waters

2006
NOAA issues 10-year plan to expand U.S. aquaculture into federal waters.

2007
Alabama, Mississippi and Louisiana ban Chinese catfish after samples are found to contain an antibiotic banned for use in fish by Food and Drug Administration (FDA). . . . FDA halts shipments of five types of Chinese fish for testing.

Proposed Organic-Fish Standards Raise Questions

Use of offshore "netpens" is controversial

Proposed standards for certifying organic aquaculture have raised complex questions about how to define an organic fish. The proposal, developed by a federal working group with strong industry representation, contains several controversial recommendations.

In general, foods that are produced without chemicals, pesticides or genetic alteration are entitled to organic certification from the Department of Agriculture (USDA). To win USDA approval, livestock must be raised on 100 percent organic feed.

Many observers argue that wild fish cannot be certified organic, since there is no way to document what foods they have eaten or chemicals they have been exposed to. This raises the question of whether farmed fish that eat feeds made from wild fish can be certified organic. In response, the working group convened by the USDA's National Organic Standards Board (NOSB) proposed two choices for feed used for organic aquaculture. Option A would allow use of fish meal and fish oil from sustainably managed fisheries, as long as such use did not exceed one pound of wild fish for every pound of aquatic animals cultured, along with scraps from processing of wild seafood for human consumption. Option B would not allow use of fish meal and oil from wild fish.

The working group proposal also would allow species raised in so-called netpens to be certified organic, as long as the pens are sited in areas where effluent discharges will not accumulate to levels that harm the environment. Closed systems, which recirculate water, are also allowed as long as they provide a healthy and high-quality growing environment.

Eager to tap into the booming organic food market, producers generally support the proposed standards, including the less-restrictive feed option A. "Diets of many aquatic animals naturally include other aquatic animals — including crustaceans, other invertebrates and baitfish," Neil Anthony Sims, whose Kona Blue company raises yellowtail in deep waters off Hawaii, wrote in a public-comment Web site. "Inclusion of fish meal and fish oil ensures an efficient, nutritionally complete diet that optimizes fish health," commented U.S. Trout Farmers Association President John Bechtel. [1]

Critics counter that using fish meal and oil is incompatible with the concept of organic production. "[T]he term 'organic' identifies a food product that has been raised under farming practices that are under direct control of the farmer, as well as the requirement that feed inputs to the process itself be organically produced. . . . At present, there is simply no way to raise carnivorous species and be true to the broadly accepted definition of 'organic,' " argued analysts Corey Peet and George Leonard of California's Monterey Bay Aquarium. [2]

Netpens are also a divisive issue. Conservationists say because netpens release untreated wastes to the environment and can spread diseases and parasites to wild stocks, finfish can only be certified organic if they are raised in ponds, tanks or other controlled production systems without direct ocean access. In practice, this approach would rule out raising most large carnivorous fish organically, at least at the outset.

The NOSB has scheduled a public symposium on organic aquaculture on Nov. 27, 2007, in Washington, D.C., to solicit more input on netpens and fish feeds. [3] Meanwhile, other seafood producers also want organic standards. Shellfish farmers say their products exemplify the idea of organic agriculture, since they improve the surrounding environment and require no feed inputs. And Alaska's Republican Sens. Ted Stevens and Lisa Murkowski have pressed for organic standards for wild-caught fish, such as Alaskan salmon, even though an NOSB task force recommended in 2001 against doing so.

"Alaska salmon is as wholesome, if not more, than any other organic product on the market," said Murkowski after she co-sponsored legislation with Stevens in 2003 that directed USDA to allow wild seafood to be certified and labeled as organic. [4]

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[1] Included in public comments on the NOSB Aquaculture Working Group interim final report, www.ams.usda.gov/nop/PublicComments/AqacultureWorkingGroupInterim/PublicCommentsAquaWGInterim.html.

[2] *Ibid.*

[3] 2007 NOSB Organic Aquaculture Symposium Call for Abstracts and Papers, www.ams.usda.gov/nosb/MeetingAgendas/Nov2007/OrganicAquacultureSymposium/CallForAbstractsPapers.html.

[4] The Associated Press, "U.S. Congress Backs Organic Wild Fish Label," April 16, 2003.

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five-year moratorium in 2001 on releasing GM fish into its coastal waters.

Lower production costs are not a strong argument for commercializing transgenic fish, says Naylor. "Fish are already underpriced in the market because prices don't reflect any of the social costs of production," such as waste discharges or coastal development, she says. "Making fish cheaper through genetic engineering shouldn't be our priority."

Berkowitz would consider putting GM fish on Legal Sea Foods' menu. "If it's deemed safe, we'd have to look at it. It would have to have the same nutritional benefit as wild fish, and I'd want character and flavor profiles before I decided to carry it. But anything that takes the pressure off wild stocks and has the potential to feed more people is good," says Berkowitz. "I don't think people truly understand what genetic engineering means or that they're [already] consuming a lot of genetically modified produce." ■

BACKGROUND

Ancient Fish Farmers

Just as humans have farmed the land and domesticated animals for thousands of years, they also have cultivated fish and aquatic plants. More than 2,000 years ago, Chinese rice farmers raised carp as a second "crop" in their rice ponds. Carvings on ancient Egyptian tombs show men harvesting tilapia from ponds. Ancient Romans also bred fish in artificial ponds, called piscinae, for food and commercial sale and as a status symbol.

Most early aquaculture involved freshwater species, since it was easier to control fish in ponds or streams than in ocean waters. Some preindustrial societies, such as Australian aborigines, built elaborate networks of canals with gates and weirs to sort and catch fish. The first ocean fish farms may have been seawater ponds that were built 1,500 to 1,800 years ago in the Hawaiian Islands. These systems had walls made of coral and lava rocks, cemented together with algae, and canals that channeled fish in and out of the ocean through movable grates. [46]

Freshwater aquaculture spread through Europe during the Middle Ages, spurred by Catholic Church doctrine that called for meatless fasting days throughout the year. Monarchs, nobles and monks harvested live fish from streams and stocked them in ponds until they were needed. After water-powered mills appeared around the year 1000, farmers began breeding carp in millponds across Europe. [47]

Rich supplies of fish and shellfish helped to draw European explorers to the New World, but by the 1800s some North American fisheries were already degraded or overharvested. In response, fish culturists began importing and breeding fish to increase supplies. By the 1850s they had learned to propagate artificially, but efforts were too limited to slow the decline of many American fisheries.

In 1871 Spencer Baird, assistant secretary of the Smithsonian Institution, persuaded Congress to create a Commission on Fish and Fisheries, with Baird in charge. The commission was the first U.S. government agency created to conserve a renewable resource. Under Baird the commission built a research laboratory at Woods Hole, Mass., and launched a broad research program on America's fisheries.

The commission also built a network of fish hatcheries and redistributed salmon, shad, trout, striped bass and other species across the nation. One venture, importing European carp as a cheap protein source for rural communities, proved to be a serious mistake — and an example of the pitfalls of introducing exotic animals to new habitats. Carp spread throughout the continental U.S. and were viewed as pests because they stirred up river and stream bottoms during feeding.

Aquaculture became part of the agricultural extension system in the early 20th century. State and federal researchers developed ways to raise new species like catfish, which local extension offices and land-grant colleges taught to farmers. In 1938, alarmed by the decline of the historic wild salmon and steelhead fisheries on the Columbia River, in the Pacific Northwest, Congress ordered the construction of large-scale hatcheries to boost fish stocks. But hatcheries could not compensate for overfishing and dam construction on the Columbia. From 1960 through 1990, up to 150 million juvenile Chinook salmon were released into the Columbia each year, but the efforts failed to produce sustained increases in harvests. [48]

After World War II the booming postwar economy created growth conditions for aquaculture, giving Americans more time and income for sports (including fishing) and travel (which exposed them to new cuisines and restaurants). Land-based agriculture shifted from small family farms to large-scale production, aided by new machines, synthetic fertilizers and pesticides and animal antibiotics. [49] Similarly, fish farming became more scientific as researchers developed low-cost feeds and standardized procedures for managing ponds and hatcheries.

The Blue Revolution

Starting in the early 1960s, aquaculture grew rapidly in the United States and around the world. Total production, including aquatic plants, rose from about 1 million tons in the early 1950s to almost 60 million tons in 2004. Nearly all the growth occurred in Asia and the Pacific. [50]

Marine experts call the jump to mass production the "Blue Revolution" in a nod to the earlier "Green Revolution" in the 1940s, when private foundations and national governments provided new high-yielding crop varieties to poor farmers in Asia and Latin America. These crops needed synthetic fertilizers and pesticides, which often caused new problems, such as making insects resistant to pesticides. The Green Revolution thus came to symbolize both the benefits and pitfalls of massive technical intervention in agriculture.

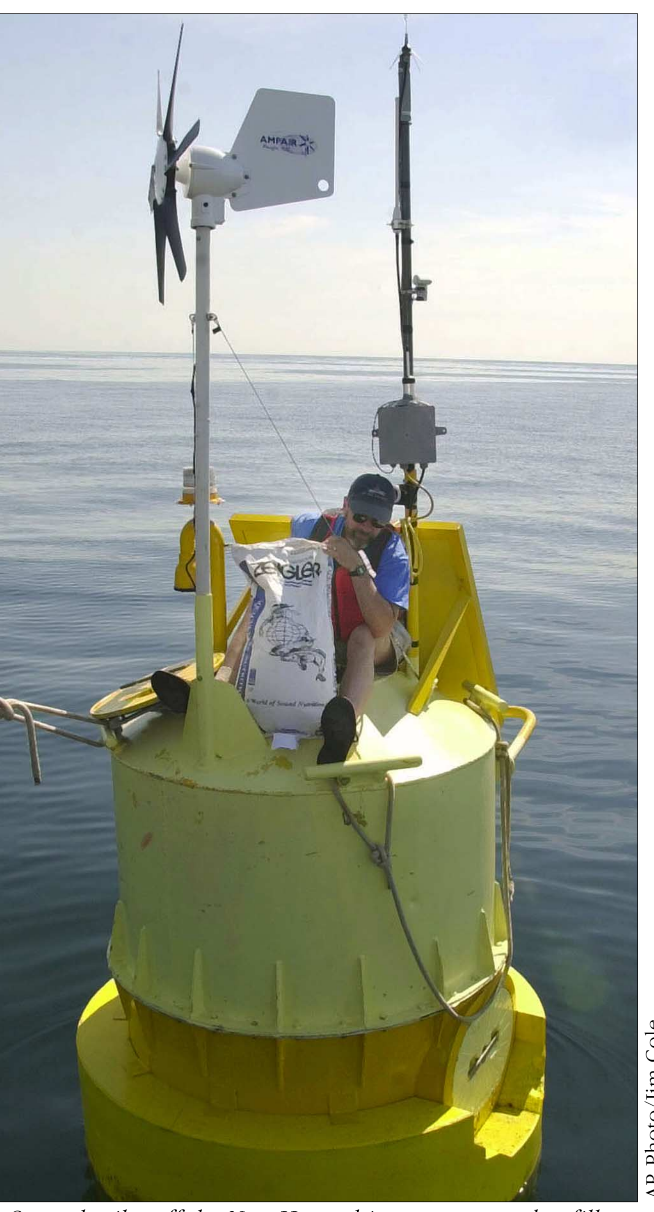
In the United States Southern farmers started building ponds on marginal croplands in the 1950s and stocking them with catfish, a popular and easy-to-raise sport fish with a mild flavor. From the mid-1960s forward the industry became an important job source in Mississippi, Alabama, Louisiana and Arkansas. By 2002 the yearly catfish crop was worth more than $400 million, nearly half the total value of all U.S. aquaculture products. [51]

Aquaculturists also started to raise marine fish and shellfish on both the East and West coasts, including salmon, sturgeon, clams, abalone and mussels. But neither wild fisheries nor the nascent U.S. aquaculture industry could keep up with consumer demand, and U.S. seafood imports rose from $360 million in 1960 to $3.6 billion in 1980. [52]

In the 1980s global aquaculture expanded rapidly, driving prices down for popular seafoods. Shrimp farming grew rapidly in Asia and South America, while commercial salmon farming became established in Norway, Chile, Scotland, Canada and Japan, as well as in Maine and Washington state. Shrimp and salmon, which had been rare delicacies for most Americans a few decades earlier, became year-round mainstays on restaurant menus.

Troubled Waters

As the industry grew, evidence mounted that poorly operated fish farms were spreading disease and competing with wild fisheries. Some of the first alarms came from the Pacific Northwest, where the Interior Department began listing wild salmon runs as endangered in the early 1990s. Competition between hatchery fish and their wild cousins, as well as overfishing and changing ocean conditions, caused Northwest salmon fisheries to collapse starting in the 1970s despite massive government investments in hatcheries. [53]



AP Photo/Jim Cole

Several miles off the New Hampshire coast, a worker fills a feeding tank that automatically feeds farmed codfish twice a day, powered by solar and wind power. The facility is part of a University of New Hampshire experiment in offshore aquaculture.

From 20 to 40 percent of the Atlantic salmon caught in the North Atlantic between 1989 and 1996 were of farmed origin. By 1997, escaped farm salmon were successfully breeding in the wild in the waters off Norway, Ireland, the United Kingdom and eastern North America. [54] Alarmed, Alaska banned finfish farming in state waters in 1989 to protect its wild salmon fishery, although salmon farming continued next door in British Columbia. In 2000 U.S. officials listed Atlantic salmon runs in eight Maine rivers as endangered, partly because of genetic mixing with escaped farm salmon. [55]

Concerns also arose about the potential for fish farms to spread aquatic diseases to wild fisheries. Epidemiological patterns indicated that salmon farms promoted the spread of sea lice, infectious salmon anemia and whirling disease to wild populations in Europe and North America. [56] Shrimp farms were also highly susceptible to disease. For example, white spot syndrome virus wiped out entire aquaculture operations in some parts of Asia and South America and threatened to spread to wild shrimp and other crustaceans via escaped shrimp, flooding, pond discharges or bird predation. [57]

Environmentalists also criticized marine fish farms as serious pollution sources and argued that the problem could grow worse as aquaculture expanded. They focused on waste discharges from ocean pens and cages, including feces, unconsumed fish food, antibiotics and pesticides.

In 2003 a U.S. district court fined two Maine companies for operating salmon farms without Clean Water Act discharge permits and ordered them to suspend operations for two to three years while surrounding areas recovered and to stop stocking European strains of Atlantic salmon. The court also denounced federal and state environmental regulators who had let the farms operate without permits.

"In the absence of any regulatory effort, inertia has reigned supreme, and the entities causing the environmental harm have been given a free pass to continue their heedless despoiling of the environment," wrote Judge Gene Carter. [58]

Consumer demand for seafood kept growing in spite of these debates as Americans sought alternatives to red meat, and researchers touted fish as a good source of lean protein. As debate widened over the risks and benefits of eating seafood, wild as well as farmed, buying fish became complicated. To help consumers and chefs make sustainable choices, ocean advocates and conservation groups published guides that typically endorsed farmed shellfish and vegetarian finfish such as tilapia, but warned users away from salmon and shrimp.

Some health experts worried that these mixed messages, coupled with government warnings about mercury in some species of wild-caught fish, could turn consumers away from seafood altogether.

"An advisory is like a medication," said Joshua T. Cohen, a senior research associate at Harvard University's School of Public Health. "It has a therapeutic effect, but it also has side effects." [59]

Cohen and colleagues calculated that if mercury warnings made people who were not pregnant cut their seafood consumption by one-sixth, risks of heart disease and stroke would rise.

In the early 2000s, two commissions carried out the first broad reviews of U.S. policies related to ocean use and conservation in more than 30 years. The Pew Oceans Commission, funded by the Pew Charitable Trusts, focused on new laws and ways to strengthen existing laws in its 2003 report. The government-funded U.S. Commission on Ocean Policy, which issued its findings in 2004, stressed better coordination between federal agencies and bigger roles for states and communities in managing ocean resources. Both groups, however, found that the oceans were in crisis as a result of overfishing, marine pollution, coastal development and poor coordination between government agencies responsible for managing ocean policies. ■

CURRENT SITUATION

Offshore Legislation

Congress is considering the National Offshore Aquaculture Act of 2007, which would authorize fish farming in federal waters. The NOAA-sponsored bill directs the secretary of Commerce to develop a process for permitting offshore aquaculture facilities in the U.S. Exclusive Economic Zone, which stretches from three to 200 miles offshore, and to establish environmental requirements for marine fish farms.

"America is at a crossroads," says Michael Rubino, director of NOAA's aquaculture program. "We're importing more than 80 percent of our seafood, and a lot of that is farmed. The choice is between growing some of that domestically or importing an increasing volume. The U.S. has very crowded coastlines, and we value them for other uses, but there's lots of space in federal waters."

Deepwater aquaculture is challenging because currents and storms are stronger, fish are more exposed to predators and it costs more to transport crews and equipment to farm sites. On the positive side, waters are cleaner, ocean currents carry wastes away from fish cages quickly and there are fewer conflicts with other activities such as recreational boaters.

"It's more expensive to farm offshore than to do it right next to the dock in calm water," says University of Alaska economist Gunnar Knapp.

Shrimp Is Most Popular U.S. Seafood

Shrimp is the most popular seafood among Americans. Canned tuna is second despite concerns about high mercury levels in some types of tuna.

Per Capita Consumption of Seafood Species by Americans, 2006
(in pounds)

Shrimp	4.40
Canned tuna	2.90
Salmon	2.026
Pollock	1.639
Tilapia	.996
Catfish	.969
Crab	.664
Cod	.505
Clams	.440
Scallops	.305

Source: National Fisheries Institute, www.aboutseafood.com

"But as more work takes place, the technical challenges of designing cages, feeders and monitoring devices will become less of an obstacle. A lot of pros and cons depend on what kinds of species are farmed, where and how." Because of high costs, offshore producers are likely to concentrate on high-value finfish like cod, halibut and snapper.

Critics say raising more large carnivorous fish will tax supplies of small fish like herring and anchovies used to make fish meal and fish oil, the main ingredients of fish feed. Raising carnivorous species often consumes more protein in the form of fish meal and fish oil than it produces, although the ratio has improved in recent years. Aquaculture already consumes almost half of global fish meal production and

three-quarters of fish oil supplies, and most forage fisheries are being fished at or near sustainable harvest levels. [60]

Many observers see the "fish for fish feed" problem as crucial to the future of aquaculture. "The feed nut has got to be cracked," says Goldburg of Environmental Defense. "If you have to catch more fish to put into a farm than you get out at the end, then marine aquaculture is ecologically nonsensical."

NOAA and fish farmers agree that the issue is serious, but they point to new options on the horizon. "These fish are eating other fish anyway, and the conversion ratio is worse in the wild," says Nardi of GreatBay Aquaculture in New Hampshire. "We've made a lot of progress on reducing the amount of fish meal in feed and replacing it with plant protein. Our industry relies on fish meal for feed, so we can't afford to have it run out."



AP Photo/Elliott Minor

Extension aquaculture specialist Pat Duncan checks a tank of tilapia at Georgia's Fort Valley State University, where she teaches fish farmers and prospective growers about aquaculture technology and potential commercial markets.

The issue is complicated because fish oil is a major source of omega-3 fatty acids, so not all substitutes have the same nutritional value. "We need more research into alternatives like marine algae," says Rubino. "All fish need protein, but it can come from many places."

Critics also argue that the NOAA legislation does not include strong environmental safeguards for open-ocean fish farming. The bill requires the secretary of Commerce, working with other agencies, to "identify . . . environmental requirements that apply to offshore aquaculture under existing laws and regulations," including issues such as escapes, disease transmission to wild stocks and impacts on marine ecosystems. The bill also calls on Commerce to "implement such measures as may be necessary to protect the environment," such as limiting or barring sites in certain areas. [61]

"We've learned a huge amount from our experience with salmon, shrimp and catfish, and we have a very sustainable and environmentally responsible aquaculture community in the United States," says Rubino. "We're going to use that same model in federal waters." But many marine experts would like to see more specific requirements.

"The bill should give some direction about where to place offshore aquaculture, based on areas' values for different uses," says Michael Tlusty, research director at the New England Aquarium. "And Commerce is required to monitor offshore aquaculture impacts, but it would be nice to do something with that data." For example, Tlusty points out, the Canadian province of British Columbia requires fish farms to cut back or halt production if impacts exceed certain limits.

Producers say Congress should not legislate prescriptive environmental standards. "If we impose too many conditions, businesses won't be able to invest in that type of production," says National Aquaculture Association President MacMillan. "You can apply conditions to prevent escapes and put bags under cages to capture waste, but that makes it extremely expensive, and we can't see how a company could afford to do that long term."

Strict environmental safeguards would yield more valuable products, argues Stanford economist Naylor. "The United States should raise the bar for aquaculture worldwide. The most sustainable producers out there are doing quite well financially and are trying to raise standards at every turn," Naylor asserts. "It makes sense in any industry. And once you generate demand and scale up production, costs start coming down."

Senior members of Congress have already signaled differences with NOAA. When Sens. Daniel Inouye, D-Hawaii, and Ted Stevens, R-Alaska, introduced the bill at the Bush administration's request, they filed amendments to address environmental risks, require more research on offshore aquaculture and forbid finfish farming in federal waters off

Continued on p. 642

At Issue:

Will offshore aquaculture benefit U.S. coastal communities?



WILLIAM T. HOGARTH
DIRECTOR, NATIONAL MARINE FISHERIES SERVICE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

WRITTEN FOR *CQ RESEARCHER*, JULY 2007

yes

Offshore aquaculture will benefit the United States as a whole, from our coastal communities all the way to the heartland. Fish and shellfish farming are integral to global seafood production in the 21st century, and the United States must embrace it or be left behind the rest of the world. Now is not the time to hide behind myths about aquaculture. Over $1 billion of seafood is already farmed in the United States under stringent regulations that protect water quality and ensure aquatic animal health. With a seafood trade deficit of almost $9 billion, the United States must take the initiative to produce more seafood here at home.

One of our best opportunities is in federal waters, three to 200 miles offshore. However, we need the right regulations in place to do that before any permits are issued. That's why the National Offshore Aquaculture Act of 2007 pending in Congress is so important. The current administration bill contains strong environmental requirements, and we are working with Congress to ensure states, councils and a long list of other stakeholders have a role in the development of a new offshore aquaculture industry.

Coastal communities, including fishermen, already play a major role in coastal aquaculture operations in the United States. In fact, aquaculture plays a significant role in many commercial fisheries, including Alaska's, where hatchery-produced salmon make up 20 to 40 percent of the catch annually. And, U.S. fishermen are among those successfully pioneering mussel and finfish farming in the ocean in Hawaii, Puerto Rico and New Hampshire. They are clearly demonstrating that offshore aquaculture is sustainable and safe.

As with any new industry, coastal communities will benefit from the economic "ripple effect" that offshore aquaculture will bring. More seafood production means more jobs, more demand for cold storage, transportation and processing. Businesses, from gas stations to boat repair and maintenance, will benefit. U.S. aquaculture can also provide fresh year-round, reliable product to help meet demand from retailers and consumers.

At NOAA, we are working on new rules to end overfishing in the United States, but even when our wild-capture fisheries are rebuilt and sustainable, they will not produce enough seafood to meet the U.S. appetite for fish and shellfish. Offshore aquaculture will ensure America's place as a global leader in both production of healthy and safe seafood and environmentally responsible seafood farming.



PAULA TERREL
FISH-FARMING AND WATER-QUALITY ISSUES COORDINATOR, ALASKA MARINE CONSERVATION COUNCIL *

WRITTEN FOR *CQ RESEARCHER*, JULY 2007

no

Coastal communities depend on commercial, recreational and subsistence fishing. But fishing is more than just "earning a living"; it is a way of life. Every new regulation, federal action or market change directly affects coastal communities. Any potential "benefit" from offshore aquaculture must be weighed against the potential social and economic loss to coastal communities and fishing families.

The National Oceanic and Atmospheric Administration (NOAA) argues that offshore aquaculture will result in fewer environmental concerns than those that have plagued coastal fish farming. But the environmental problems associated with near-shore fish farming don't go away just because you move offshore. These risks include escapes of non-native species, ocean pollution, use of chemicals, spread of disease and, more recently, the development of genetically modified fish that will be used as brood stock for farmed species.

NOAA would have us believe that offshore aquaculture will complement wild fisheries. Rather, it is clear that it will compete with existing wild fisheries, especially finfish such as salmon, halibut and cod. Consider:

- Denying fishermen access to their fishing grounds is likely to cause conflicts.
- With offshore aquaculture focusing on carnivorous finfish, such as black cod and halibut, coastal communities will be negatively affected by market confusion about healthy, wild seafood.
- Farming of species that are healthy and are commercially harvested in the wild will compete with, rather than complement, wild fisheries.

NOAA also asserts that offshore aquaculture will provide jobs in coastal communities, but the facts show that:

- The high cost of tending fish far from shore means facilities will likely be automated.
- Mom-and-pop operations will not survive, and operations will be consolidated into a few multinational corporations.
- The United States cannot compete with lower labor costs in other countries.

Offshore aquaculture should not be a substitute for good fisheries management. In places where there are depletions, rebuilding plans and other conservation tools should be used to restore fish populations.

** Terrel and her husband have owned and operated a salmon trawler for 29 years.*

Continued from p. 640

Alaska. Inouye announced he would also offer a comprehensive bill to address further concerns with NOAA's approach. [62] Inouye and Stevens' actions reflect worries in some coastal communities about the impacts of expanding offshore aquaculture. (*See "At Issue," p. 641.*)

Seafood Safety

Recurring contaminants in imported farmed seafood, along with similar problems in other food sectors, are spurring Congress to pass new laws regulating food safety. China, the source of many tainted food products, appears to be feeling the heat, although it is not clear how quickly Chinese regulators will be able to reform the nation's vast production system, largely made up of smaller farmers. [63]

On May 9, the Senate passed an amendment calling on the FDA to expand seafood inspections and report to Congress on the feasibility of developing a tracer system for all domestic and imported seafood. "It is unacceptable to allow substandard catfish and shrimp, mostly produced in China, to enter the U. S. market when those imported products do not meet the established safety standards that govern our food supply," said Sen. Jeff Sessions, R-Ala., who sponsored the measure. [64]

The bill also included an amendment offered by Sen. Richard J. Durbin, D-Ill., designed to strengthen the nation's food system by creating an early-warning system for food contamination and a registry of adulterated-food cases and requiring companies to maintain records that would help the FDA trace contaminated food. The measure also states the sense of the Senate that the FDA needs more resources and inspectors and that the agency should place priority on negotiating food safety agreements with other countries.

Between 2003 and 2007, however, Congress reduced FDA's budget for inspecting foreign seafood-processing plants from $211,483 to zero. [65] While the program was small, critics say inspecting more foreign plants would help FDA to identify potential risks from imported seafood before shipping. Congress could restore the funding when it considers FDA's budget later this year as part of the fiscal 2008 Agriculture appropriations bill. The FDA, which oversees all food except meat and poultry, has 1,962 inspectors to police nearly 300,000 plants in the United States and abroad. [66]

In late June, just before the FDA banned five types of Chinese farmed fish from entering the United States without testing, regulators in Beijing disclosed they had identified more than 23,000 food-safety violations and closed down 180 food plants in a national crackdown over the previous six months. Problems included use of malachite green in seafood and processing of shark fin with toxic industrial chemicals. [67]

China may be trying to clean up its quality problems, but reforms are likely to come slowly. According to importers and inspectors, most Chinese fish is raised by small family farmers who have to contend with serious industrial water pollution and who know very little about the chemicals they use. [68] And China's poorly organized regulatory system, which is riddled with corruption, gives producers few incentives to meet high standards. As a first step, Sen. Durbin and Rep. Rosa DeLauro, D-Conn., chairwoman of the House Appropriations Subcommittee on Agriculture, have called for negotiating an agreement that would allow FDA inspectors into China. [69]



AFP/Getty Images/Francis Kohn

Senior scientist Atle Mortensen is studying cod aquaculture at the Norwegian Institute of Fisheries and Aquaculture Research in Tromso. Farmers have perfected salmon aquaculture, but raising the endangered cod is trickier.

U.S. consumers who are worried about seafood safety can get some information from country-of-origin labels (COOL), which have been required on fresh and frozen seafood products (but not canned or processed goods) since 2005. The labels also specify whether products are wild-caught or farmed. But many Americans don't read them, says the aquaculture association's MacMillan: "Consumers don't necessarily distinguish between domestically produced fish and fish that's produced abroad or captured in the wild — they buy cheaper fish from countries with lower labor costs. Sometimes that approach comes back to bite them."

University of Alaska economist Knapp agrees that most U.S. consumers know very little about fish, but he says retailers are asking for much more information about seafood products. "Large buyers like Wal-Mart, Safeway and Whole Foods have a very strong incentive only to buy healthful foods. These companies are going to start demanding 100 percent traceability and the ability to audit all along their supply chains," he says. "When markets depend on those conditions, the system will be really reliable."

In fact, Wal-Mart and other large buyers already have adopted standards drafted by the Global Aquaculture Alliance, an industry group, which has set minimum environmental and social conditions for fish farming. While some environmental groups say that industry standards could be stricter, enforcing these codes will help to establish some basic standards for aquaculture, such as cleaning up water discharged from fish farms and ending use of antibiotics.

The new standards are prompting some suppliers, including shrimp farmers in Thailand, to improve their operations and restore environmental damage. For example, Rubicon Resources, a Los Angeles-based supplier of Thai shrimp, has replanted new mangrove swamps to compensate for trees destroyed to make way for its ponds and has standardized treatment of discharged pond water. [70] ■

OUTLOOK

Seeking Sustainability

As Congress considers authorizing offshore aquaculture or requiring more study, pressure to farm the seas is growing worldwide. Meanwhile, issues such as food-conversion ratios and effluents from fish cages are being considered in the debate over how to conduct large-scale aquaculture without harming the oceans.

Many researchers are developing equipment and methods to minimize environmental impacts. Several companies are patenting rigid spherical cages for ocean finfish farming that are engineered to withstand storms and shark attacks. Researchers are also studying ways to grow shellfish in deep water on submerged lines or platforms.

Another low-impact approach is to adapt marine species to grow in freshwater tanks. Florida's Ocean Boy Farms grows Pacific white saltwater shrimp in low-salinity ponds and uses specially cultivated bacteria to consume shrimp wastes. [71] Other producers are raising game fish like cobia and barramundi at facilities far from the coast in Virginia and Massachusetts. [72]

Using less fish for fish food is a high priority. Some improvements are low-tech. For example, Kona Blue Water Farms, which raises Hawaiian yellowtail in state-controlled deep ocean waters off Hawaii, feeds its fish once a day instead of multiple times so that they devour the food quickly and let very little drift out of their cages. The approach produces one pound of fish from one pound of feed. [73]

Researchers have had trouble finding substitutes for fish meal and fish oil that contain the omega-3 fatty acids and other nutrients that fish need to grow, but some companies are starting to derive these nutrients from sources such as marine algae and polychaete seaworms. In February a Maryland company, Advanced Bionutrition, released a new shrimp feed that completely replaces fish meal and fish oil with nutrients from sustainable sources.

Sustainability is also a social issue, says the University of Rhode Island's Costa-Pierce, who questions whether ocean farming will benefit coastal communities. "It's at a primitive stage of planning, and there's been no discussion of all the other pieces besides production, like hatcheries and transportation," says Costa-Pierce. He is much more enthusiastic about the growth in coastal shellfish farming. "An enormous number of fishermen are fishing part time and raising shellfish part time. That's a very exciting transition because it's an additional enterprise that fits into their lifestyles socially, economically and environmentally."

In the view of the University of Alaska's Knapp, however, aquaculture will benefit fishing communities in the long run by making the economic pie bigger for all fish producers. "Aquaculture is vastly expanding consumer demand for fish," he explains. "It's going to turn people into fish eaters by making fish available and getting them to think about trying it. Farmed salmon can't keep up with demand even though there's three or four times as much salmon in the world now as there was 15 years ago, because they've increased demand so rapidly."

But aquaculture has to be economically sustainable for producers to undertake it. Some experts question whether ocean fish farms in U.S. waters can compete with imported farmed fish. "There's been no hard-nosed economic assessment of the economic viability of cod, haddock and some of the other species that are being tested, and the operations that are making money in Hawaii are in state waters near the shore," says Costa-Pierce.

The economics are especially challenging for companies trying to develop new sustainable approaches, says Nardi of New Hampshire's GreatBay Aquaculture. His company is researching new designs for submersible cages and substitutes for fish meal, and it recirculates water at its dry-land hatchery to minimize discharges.

"We can't do it on our own. We need to team with other people at universities and agencies to get grants and work on these measures until we can see whether they're economically viable" says Nardi. Still, he believes that U.S. aquaculture can and should expand: "If people knew that a big share of their seafood supply is farmed and a growing share will come from farms, they would agree that it makes sense for us to participate in it." ■

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